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A Preliminary Report on Volatile Organic Compound Emissions from Gasoline Marketing in the Lower Mainland

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A PRELIMINARY REPORT ON VOLATILE ORGANIC COMPOUND EMISSIONS FROM GASOLINE MARKETING IN THE LOWER MAINLAND

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Task Force Report to the

Lower Mainland Oxidants Steering Committee

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1. INTRODUCTION

The first report of the Steering Committee for the Lower Mainland Oxidants study, prepared in 1984, presented a number of recommendations on research activities that should be implemented and ozone control options that should be examined. A task force comprised of E.P. Wituschek, Environment Canada, K.K. Bhattacharyya, Ministry of Environment and Parks, and P.B. Beauchemin, Greater Vancouver Regional District, has reviewed volatile organic emissions from gasoline marketing in the Lower Mainland with the view to identifying potential emission reduction options.

2. THE FUEL MARKETING NETWORK

2.1 General

The inherent composition of gasoline yields a fuel with a high vapour pressure in comparison to other fuels. The volatility of gasoline and attendant safety considerations require special handling procedures and storage facilities. The composition of the vapour is related to the bulk composition of the liquid phase, and many of the volatile components, referred to as volatile organic compounds (VOC), are photolytically reactive in the atmosphere and contribute to the formation of ozone. The gasoline vapour, especially some of its constituents such as benzene, additives like ethylene dichloride, ethylene dibromide, and tetraethyl lead is regarded as toxic and has been investigated in studies of health impacts on workers handling gasoline as well as on the public, particularly from the exposure during vehicle refueling. The ensuing sections describe in general terms, the sources of emissions in the gasoline marketing network, control options and suggested approaches to phasing in VOC controls.

VOC emissions arise from various operations in the fuel distribution network that moves gasoline from the refinery to its end consumption. Figure 2-1 displays the main elements in the wholesale and retail network. The flow of gasoline through a typical marketing network is shown from the

refinery through bulk terminals, bulk plants, barges, and tank trucks to retail outlets or commercial or rural dispensing facilities. The wholesale portion of the network includes storing and transporting the gasoline to a service station underground tank or commercial account while the retail portion includes the vehicle refueling operations.

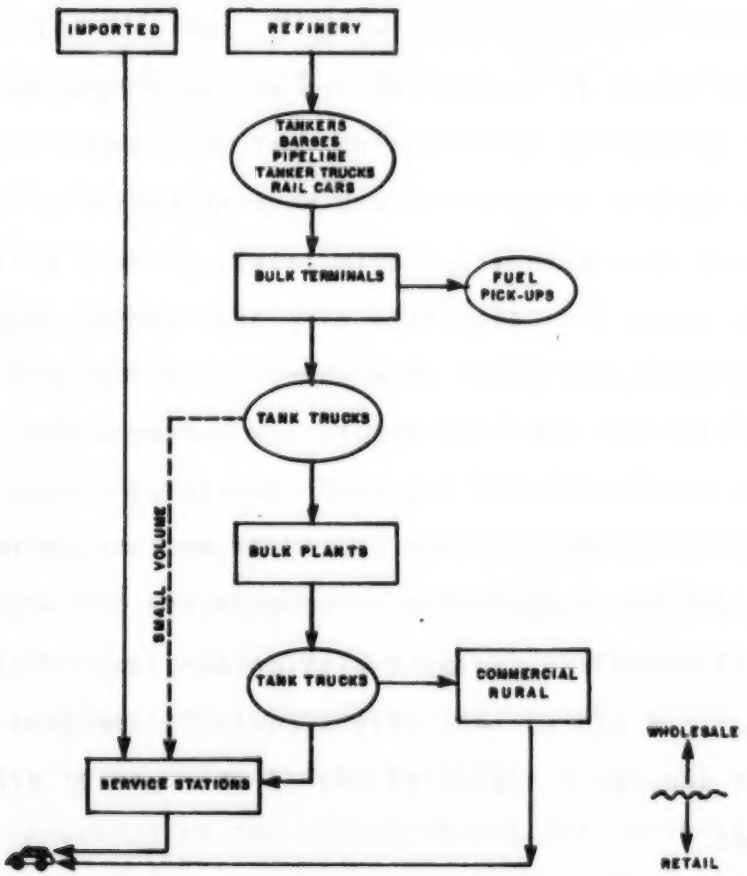

FIGURE 2-1: GENERALIZED GASOLINE MARKETING NETWORK

2.2 Bulk Terminals

Bulk terminals commonly serve as the major distribution point for gasoline produced at refineries or imported. Gasoline is stored in large above-ground tanks at the terminals and is pumped through metered loading areas, called loading racks, into tank trucks which service various wholesale and retail accounts. In the Lower Mainland, the bulk terminals are linked by pipelines to the respective local petroleum refineries.

Large storage tanks at the refineries and bulk terminals have an external or an internal floating roof to prevent the loss of products through evaporation and working losses. Floating roofs rise and fall with the liquid level, thereby avoiding a large vapour space and associated displaced vapour emissions. Working loss emissions occur when there is an improper fit between the seal and the tank shell, and during withdrawal when the wet tank walls are exposed. Breathing losses, which are of a smaller magnitude, are dependent on tank design factors and ambient temperature. The majority of large floating roof tanks are equipped with primary seal roof designs which can can achieve 60-90% control depending on the type of roof and seals installed and on the type of organic liquid stored.

A primary seal serves as a vapour conservation device by closing the annular space between the edge of the roof and

the tank wall. Additional vapour control can be achieved by floating roofs equipped with secondary seals.

2.3 Bulk Plants

Fixed roof tanks, some with pressure-vacuum vents, are used for the smaller capacity storage tanks at bulk plants and commercial storage depots. Emissions from fixed roof tanks occur due to breathing losses and working losses. The greatest emissions are due to the displacement of vapours during filling. Displaced vapour emissions can be controlled with vapour collection systems such as carbon adsorber, thermal oxidizer or refrigerated condenser. Control efficiency can be over 90%.

2.4 Tank Trucks

Emissions from tank trucks loading at bulk terminals or bulk plants occur when the product being loaded displaces the vapour in the tank truck to the atmosphere. The quantity of emissions depends on the type of loading. Splash loading into the top of the fuel compartment creates considerable turbulence and mist, and emissions are substantially higher than from quiescent submerged loading which uses either a fill pipe extending below liquid level, or a piping connection at the bottom of the fuel compartment. There is about a 60% reduction in emissions when using submerged top or bottom loading. Although no regulations have been prescribed in B.C. for tank loading system designs, the

industry has largely converted to submerged loading as a fuel conservation measure.

More recent vapour control technology for truck loading operations involves transferring the vapours via piping back to the tank being emptied. This so-called vapour balance configuration is feasible when loading trucks from fixed roof storage tanks but is not feasible when loading from floating roof tanks. Vapour capture efficiencies in the range 90-95% are attained with vapour balance systems.

When trucks are loaded from floating roof tanks, the vapours cannot be returned and a vapour collection system such as carbon adsorber, thermal oxidizer or refrigerated system can be installed which can achieve 90-98% control efficiencies.

Tank trucks not equipped for vapour balance service are themselves a source of emissions due to evaporative losses from the hatches on the fuel compartments. Trucks fitted for vapour balance loading and unloading are equipped with vapour domes that enclose each top hatch along with ancilliary vapour transfer piping. This vapour containment design achieves a high degree of control. However, the trucks so equipped require maintenance and regular leak testing to ensure that the fittings are maintained vapour tight.

2.5 Service Stations

Emissions at service stations result primarily from the filling of the underground storage tanks during tank truck unloading, and a small contribution is from the evaporative losses through the tank vent. Emissions from the underground tank filling operation can be reduced significantly, up to 95%, by using a submerged filling pipe and vapour balance that transfers the displaced storage tank vapours back to the tank truck, rather than venting the vapours to the atmosphere. At the bulk plant or terminal, the truck vapours are transferred to the storage tank or captured in a vapour recovery system as the truck is loaded. The actual in-use efficiency of service station vapour balance systems has been estimated to vary in the range from 62% to 86% depending on the level of compliance monitoring.

2.6 Vehicle Refueling

Vehicle refueling emissions are a larger source of emissions than those from filling the underground storage tanks even though the displaced fuel volumes are the same. Fuel tank temperature differences are one reason, and spillage of fuel onto the ground during vehicle refueling is another. Spills and nozzle drippings may account for about 4-5% of the total refueling emissions.

Refueling emissions can be controlled by installing a vapour balance system at the service station, or by control systems

on the vehicle. The vapour balance system transfers the displaced vapours from the vehicle fuel tank back to the underground storage tank via a special hose design on the dispensing pump. Vapour balance can achieve 95% control but in-use efficiency can drop to 60% unless there is a reasonable level of enforcement.

Onboard vehicle control systems require a fillpipe seal and a carbon canister on the vehicle. While onboard controls are a feature on contemporary cars to control carburetor vapours and diurnal evaporative emissions from the fuel tank, recent studies have shown that the adsorptive capacity and regeneration capability of the carbon adsorber is not sufficient to adequately control these emissions, let alone the additional displaced vapours during vehicle refuelling.

If onboard vapour controls were re-designed to capture the displaced vapours during vehicle refueling, control efficiencies in the range 95-98% can be achieved, although actual in-use efficiency is lower and has been estimated 92%, taking into account some tampering. New higher capacity carbon canisters would also provide additional reductions in the evaporative emissions from the engine fuel systems in comparison to the undersized canisters on contemporary cars.

Emissions associated with fuel spillage cannot be controlled

with either of the refueling controlling options and remain a constant loss.

In comparing the two control approaches, it is apparent that the emission reductions of onboard controls are dependent on the retirement rate of the in-use vehicle fleet. The emission reduction of the vapour balance option will be dependent on the rate at which service stations are retrofitted with the technology. The latter approach is expected to be less effective overall since the small service stations with low gasoline throughput would likely be exempted from installing the vapour balance controls. Capital and operating costs and other factors will need to be examined to further assess the relative merits of these two approaches.

3. GASOLINE VAPOUR PRESSURE

The composition and quantity of VOC emissions from gasoline are sensitive to the fuel composition, the vapour pressure and the ASTM distillation curve. The gradual, but steady volatility increase of alcohol-free gasoline over the past decade is linked to the North American trend to reduce lead in gasoline with the consequent need to replace the lead's octane-boosting role with high-octane components. The crude refining process for low lead gasolines is more demanding and this yields more of the higher octane components as well as more butane. Because butane is a good front-end octane enhancer, and for economic reasons, the petroleum industry have allowed it to remain in gasoline. Butane however increases fuel volatility. Reid Vapour Pressure (RVP) is one of the indicators used to characterize fuel volatility.

The American Petroleum Institute has suggested that regional ozone control strategies in the U.S. consider a limit on vapour pressure during months when ambient ozone levels are elevated. A reduction in the vapour pressure of gasoline will reduce evaporative emissions associated with all of the loading and storage operations in the marketing network, as well as reduce the evaporative emissions from the carburetor and fuel tank on the vehicles. The lower volatility is achieved by lowering the butane content in gasoline and requires increasing the other high octane components. The

evaporation of gasoline spilled during vehicle refueling, however, will not be affected.

Studies in the U.S. have estimated VOC evaporative emission reductions in the range 20-28%, when applied to the uncontrolled emissions across the marketing network, based on reducing the in-use RVP of commercial gasoline from 11.5 psi to 9.0 psi. The average summer RVP of commercial gasoline in the Lower Mainland is 10.4.

This indirect control approach to reduce VOC emissions can be implemented in selected regional gasoline markets and should be considered in the context of an ozone control strategy for the Lower Mainland. However, a volatility limit on gasoline may require processing adjustments at the refineries supplying the Lower Mainland gasoline market and affect the pricing of gasoline and butane. Consequently, these implications need to be examined in further detail.

4. ESTIMATED VOC REDUCTIONS

Table 4-1 displays the major sectoral emissions of VOC's in the Lower Mainland. Gasoline marketing accounts for about 8000 tonnes, or about 10% of the estimated total annual emissions. The proportion is comparable to the emission inventories of other cities. The estimate is approximate since it is derived by prorating province-wide gasoline marketing emissions, on a population basis, to the Lower Mainland. Nevertheless, it appears to be a reasonable estimate for the marketing network as a whole when compared to the 1983 PACE study estimate of 5800 tonnes for Vancouver that includes only the emissions from vehicle refueling, filling of service station underground tanks and fuel transfers at commercial facilities.

TABLE 4-1 ESTIMATED VOC EMISSIONS IN THE LOWER MAINLAND

Source Sector	1980 VOC Emissions(%) (Total 86000 Tonnes)
Gasoline powered vehicles	
automobiles	28
light duty trucks	7
medium duty trucks	4
heavy duty trucks	6
other	2
Petroleum refining	10
Gasoline marketing	10
General solvent use	5
Diesel powered engines	5
Stationary fuel combustion	1
Other	22

A first order segregation of the fuel transfer operations suggests that basically three fuel transfers take place; namely, loading of tank trucks at the bulk terminals, transferring fuel from tank trucks to service station underground storage tanks and transferring fuel to vehicles. A portion of the gasoline moves through commercial accounts which occurs subsequent to the bulk terminals and is, in effect, a parallel operation to the service stations when considering emissions. The PACE study estimated the

emissions from vehicle refueling, filling of service station underground tanks and commercial accounts at about 2200, 2200, and 1400 tonnes respectively for a total of 5800 tonnes. This leaves about 2200 tonnes of VOC emissions for the truck loading operations.

Three main approaches to VOC emission reductions can be identified as follows:

(a) Controls on the wholesale segment

If vapour balance technology were applied to tank truck loading operations and vapour balance or vapour capture technologies to the storage facilities, an 80% reduction, as a rough approximation, can be achieved across the wholesale portion of the network. For the 5800 tonnes of uncontrolled emissions, this control efficiency will achieve a reduction of about 4600 tonnes. The emissions after control will be about 1200 tonnes.

The total marketing emissions will be about 3400 tonnes when the controlled emissions within the wholesale segment are added to the uncontrolled vehicle refueling emissions.

(b) Controls on the wholesale segment + vehicle refueling

Emissions from vehicle refueling can be controlled by either vapour balance technology as a hardware component of the service station or controls onboard the vehicle. Assuming a

conservative control efficiency of 80% for either approach, the uncontrolled vehicle emissions of 2200 tonnes will be reduced by about 1800 tonnes. Consequently, the controlled emissions will be about 400 tonnes. The full benefit of the former approach will not be achieved until new cars displace the existing vehicle fleet, which will be in about ten years.

For the marketing network as a whole, including controls on the wholesale segment, the total emissions will be about 1,600 tonnes.

(c) Control option B + RVP reduction to 9.0 psi

If a restriction is applied to commercial gasoline during the summer months that limits the RVP to 9.0 psi from the current 10.4 psi, the marketing emissions will be reduced by about 200 tonnes (ie. 15% reduction is applied to fuel sales during the 3 month ozone season).

Total marketing emissions will be reduced to about 1400 tonnes.

Figure 4-1 summarizes the emmission reductions discussed in the preceding paragraphs.

A study is currently underway to develop detailed estimates of VOC emissions for the Lower Mainland. This study will provide the necessary information to refine the currently

available preliminary data.

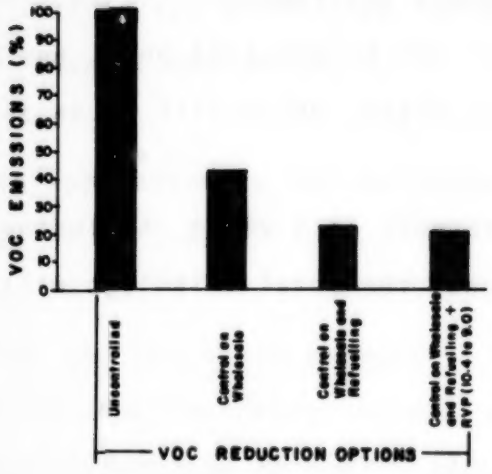

FIGURE 4-1 VOC REDUCTIONS WITH DIFFERENT CONTROL OPTIONS

Studies on capital and operating costs of VOC emission controls have not been undertaken for the Vancouver area, nor for other urban centres in Canada. However, gasoline vapour control programs have been identified and implemented as essential components of ozone control strategies in non-attainment air quality regions in the U.S. The majority of the non-attainment areas have implemented controls for the wholesale segment, and two areas have implemented controls for both the wholesale segment and for retail level vehicle refueling. One jurisdiction has, in addition, implemented a summertime restriction on gasoline RVP to 9.0 psi and is considering lowering the limit to 8.0 psi.

The concept of VOC emission controls is viewed as a prudent objective recognizing that further technical and cost studies need to be done. A control program implemented in the Lower Mainland can serve as a prototype program to thoroughly assess the costs and effectiveness of VOC reductions from gasoline marketing on ozone air quality.

5. RECOMMENDATIONS

Having regard to the discussions in the previous sections, a number of follow-up actions are recommended in order to assess the relative technical merits and optimum cost-effectiveness of control approaches for the Lower Mainland.

(1) The three levels of government, in concert with industry, should undertake a detailed assessment of control technologies and costs associated with VOC emission controls from the various operations within the gasoline marketing network in the Lower Mainland. This assessment should identify the most cost-effective control options for each of the fuel transfer operations, transportation modes and storage facilities.

(2) Environment Canada and the petroleum industry should review the volatility characteristics of commercial gasoline and determine the cost benefits of reducing the summertime vapour pressure to 8.0 or 9.0 psi.

(3) Environment Canada should assess the feasibility of modifying onboard vehicle controls for new vehicles to control refueling emissions and evaporative emissions from the fuel tank.

(4) The Greater Vancouver Regional District should review

existing control measures for fixed roof and floating roof gasoline storage facilities and ensure that effective control measures are applied.

(5) The planned review and update of the provincial Pollution Control Objectives for the Chemical and Petroleum Industries is timely and offers an opportunity for considering control technology options for liquid petroleum storage tanks.